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The Production of Underwater Sound by *Opsanus* sp., a New Toadfish from Bimini, Bahamas[1,2,3]

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(Plates I-III; Text-figs. 1-5)

INTRODUCTION

DURING investigations into the occurrence, character and significance of underwater sounds produced by subtropical marine species, two toadfishes were auditioned at the Lerner Marine Laboratory, Bimini, Bahamas, in December, 1952. These specimens were temporarily labelled *Opsanus tau*[4], but the fact that the recorded sounds differed from those of the many *O. tau* already studied in continental waters was noted in our report. Similar soundmaking by Bimini toadfishes was recorded in December, 1956, and April, 1957. Acordingly these alternatives were presented: (1) sound production within one species varies geographically far more than previously supposed; or more probably, (2) the experimental specimens were not *O. tau*.

That Bimini toadfishes are not *O. tau* but a previously undescribed species, as subsequently established by Walters & Robins (MS), suggests that in some cases quality and pattern of underwater sounds may constitute a diagnostic specific character. Such differentiation can be of particular value toward identification of field contacts.

EXPERIMENTAL PROCEDURE

All specimens were collected at low tide from the shallow flats of Tagus Key, within the Bimini lagoon. Immediately after capture they were transferred to glass aquaria for close observation and frequent monitoring, and during actual recording to a wooden tank insulated by a thick lining of Hairflex, rubberized horsehair.

The 1952 monitoring system consisted of a NOL Type 1-A, Model Q4, quartz crystal hydrophone with an amplifier modified from JO Underwater Sound Equipment. Recordings were made on a Magnecord PT63 at a tape speed of 15 inches per second. During 1956-57 a more compact AN/SSQ-2 barium titanate hydrophone, modified for this purpose by the authors, was used. Recordings at fixed locations were made on a Magnecord F35-B, and a Magnemite

[4]Rough identification was based on reticulated color pattern and distribution, which favored *O. tau*, the only toadfish reported along the Atlantic coast from Maine to Cuba, rather than *O. beta*, a Gulf of Mexico species known to stray rarely as far north as Biscayne Bay.

610-VU battery-spring operated recorder was used for field listening and recording.

Frequency analysis of the recorded sounds was accomplished by three methods. The pressure amplitude distribution was determined by a Western Electric RA-363 filter set having 12 overlapping octave ranges. A General Radio 760-B sound analyzer was used to separate the major individual frequency components. Photographs of the sounds displayed on a Dumont 304-A oscillograph were used with a Dumont 296 oscillograph camera to allow detailed examination and comparison, and to provide accurate time and frequency measurements.
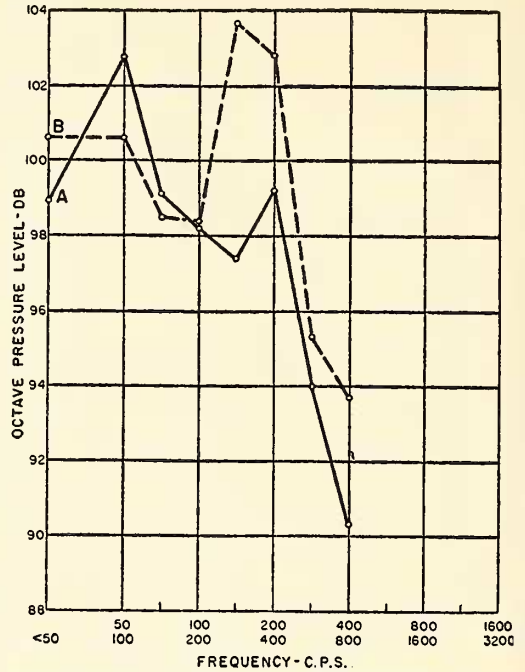
Recorded Sounds

Type I Sound.—An immature female (specimen #1) measuring 165 mm. in total and 140 mm. in standard length, which had been held under observation for three weeks[5], was used for experiment on December 1, 1952. Routine stimulations involving changed environment, mild aggravation and extreme duress gave negative results; no biological sound could be stimulated thus. However, when electrically stimulated by 60 cycle a-c shock, a low vibrant grunt was consistently produced, coincident with each instantaneous shock. These apparently involuntary sounds exhibited a fundamental frequency of 60 cycles with strong second and fourth harmonics; all harmonics to the tenth were measurable.[6]

As shown by Text-figs. 1 & 2, this type of Bimini toadfish growl is very similar in frequency pattern to the characteristic coarse growl of *O. tau.* However it is a more sustained and less raucous sound. Over-all pressures of 104.7 to 111.05 db above 0.0002 dyne/cm^{2} were registered at a distance of two feet from the hydrophone; under the same electric stimulation *O. tau* sounds regularly measured under 106 db and only rarely reached 108 db. These slight differences between the two species are not significant since intensity, influenced by size of individual and degree of stimulation, may be expected to vary considerably within a single species.

[5]Because of the tendency of most fishes to remain silent when confronted with strange situations, especially in the presence of vessels and underwater gear, an attempt is made to acclimate specimens to the experimental area and equipment over as long a period as possible.

[6]In the case of *O. tau* (Fish, 1954), electrically induced grunts differed from the spontaneous grunts only in a widening of frequency range; the fundamental frequency was predominantly the same. Experiments using electrical stimulation with d-c and a-c of various frequencies indicated that the natural fundamental frequency of the sounds was not a result of the 60 cycle stimulation.

Text-fig. 1. Type I sounds of specimen #1, an immature female recorded at Bimini in 1952. Curve **A**: average of 4 sounds, over-all pressure 104.7 db. Curve **B**: average of 2 sounds, 104.9 db.
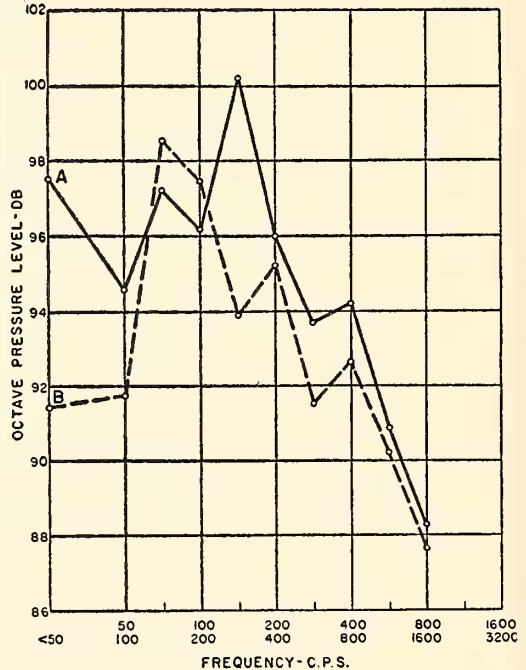
Text-fig. 2. Composite of sounds produced by 7 specimens of *O. tau* recorded in Rhode Island in 1951. Curve **A**: average of 10 sounds from 3 specimens. Curve **B**: average of 15 sounds from 5 specimens.
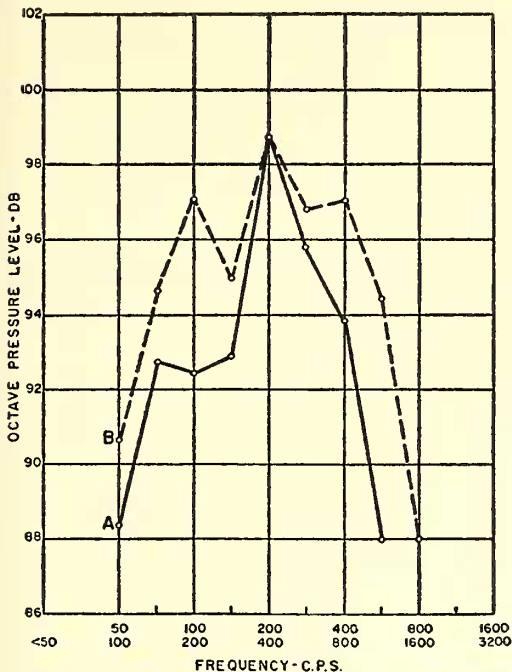
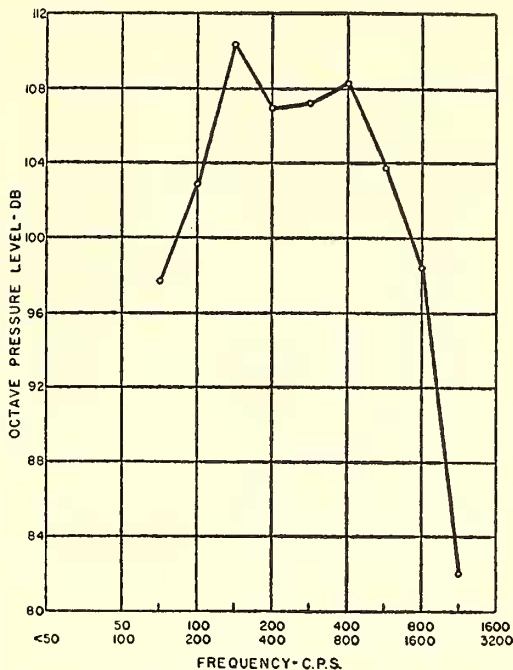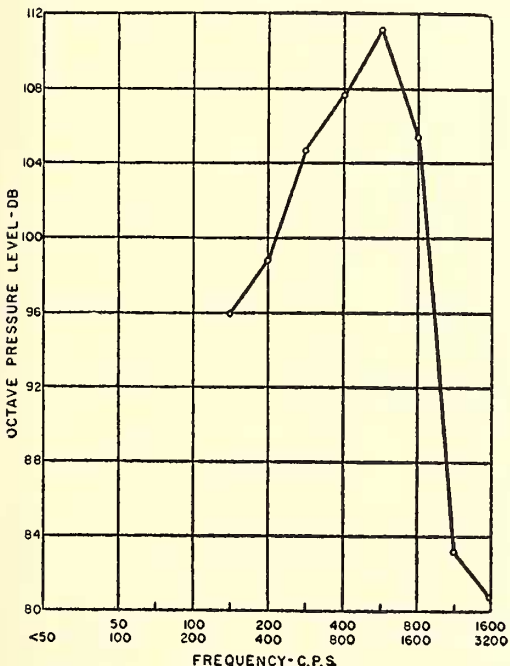TEXT-FIG. 3. Type II sounds of specimen #2, recorded at Bimini in 1952. Curve A: average of 2 sounds, over-all pressure 100.9 db. Curve B: average of 2 sounds, 102.3 db.

TEXT-FIG. 5. Sounds from specimen #5, an immature male recorded at Bimini in 1956. Average of 15 sounds, over-all pressure 110.95 db.

Type II Sound.—Specimen #2, measuring 115 mm. in total and 100 mm. in standard length, was subjected to the same series of stimulations on December 17, 1952. When handled, prodded gently or aggravated to attack, a more protracted and rather musical burst was emitted. The same sound was produced by electric stimulation but, unlike the Type I sound which was coincident with shock, occurred only after release from shock. The fish reacted to small instantaneous shock by a slight muscular shudder and extension of opercula and fins, followed, after release from shock, by the rumbling burst. (Text-fig. 3).

Of the three 1956-57 toadfishes, only two could be induced to sound production. On December 21, 1956, long bursts were emitted immediately and over a long period when a male with well developed gonads (specimen #3) was caught in the meshes of a net; its total length was 121 mm. and standard length 105 mm. On April 15, 1957, similar bursts were recorded from an immature male (specimen #5) measuring 110 mm. in total and 89 mm. in standard length. However, on January 3, 1957, a female with partially spent ovaries (specimen #4), measuring 89 mm. in total and 80 mm. in standard length, could not be stimulated to sound-making, even by extreme duress. Whether her silence was due to sex, breeding condition or

TEXT-FIG. 4. Average of 10 sounds from specimen #3, a mature male recorded at Bimini in 1956. Over-all pressure 111.7 db.

merely individual reticence cannot be determined without data from more specimens.

The sounds produced by specimens #3 and #5 differ considerably from any previous toadfish recordings. Those of the mature male (#3) range between 634 and 800 cps, and thus are much higher in frequency than the normal grunts of this species, the grunts and boatwhistles of *O. tau* (Fish, 1954) and of *O. beta* (Tavolga, 1958). Analysis of these sounds (Textfig. 4) shows very little harmonic content, which is confirmed by the comparatively good wave form on the oscillographic record (Plate I, Fig. 1). A small second harmonic is measurable.

Closer observation indicates that many sounds heard as a single pulse actually consist of two distinct pulses separated by a short interval (Plate I, Fig. 2). While these pairs have the same general characteristics as the single sounds, the repetition frequency and duration are more variable within each group and among different groups. The sounds may occur as isolated single or paired pulses, but usually occur in rapid bursts of two or more groups containing random combinations of single and paired pulses. The shorter bursts consist of less than 10 groups produced at rates ranging from four to nine groups per second, averaging about five. In longer bursts, the groups are produced at a slower rate; the longest burst measured 38 seconds duration and contained 82 groups of both single and paired pulses.

To the unaided ear the sounds of the smaller, immature male #5 appear quite similar to those of the mature male #3, but analysis shows a much lower fundamental frequency with many harmonics to about 1100 cps (Text-fig. 5). The probable fundamental ranges between 105 and 145 cycles, comparable to the Type II sound of the 1952 specimens, and is weak in comparison to large second and fourth harmonics. The oscillographic records show these complex wave forms with apparent repetition frequencies between 217 and 286 cps, *i.e.,* second harmonics (Plate I, Fig. 3).

This specimen produced the same doublepulse sounds as #3, with even greater variations. As shown in Plate I, Fig. 4, and Plate II, Figs. 5 & 6, the sound duration, principal frequency and wave form change within any given group, and no two groups are identical. Detailed analysis of a single-pulse burst indicates a number of harmonic components differing in frequency by only a small percentage of the fundamental frequency, similar to the difference observed in the double sounds.

Because the sound-stimulating intrinsic muscle masses meet posteriorly but do not fuse (see p. 75), it is possible that contraction of the two sides of the air bladder are not always coincident, and could, therefore, result in a double sound. Moulton (1956) suggested a slightly asynchronous contraction of the two drumming muscles of the sea robin (*Prionotus* spp.) as the probable cause of a paired arrangement of pulses in its breeding season calls.

Although externally the bilobed air bladders of sea robin and toadfish are much alike, their internal structure differs. In the sea robin the two lobes are more narrowly connected, forming dissimilar compartments, whereas those of the toadfish open widely and function as a single chamber (Plate III, Fig. 9). Under these conditions, less variation would be expected in toadfish double sounds, and the slight difference in frequency content between the two parts of such sounds might be explained accordingly. On the other hand, Moulton recorded a difference of 1,000 cycles in intensity peaks of sea robin double sounds, "probably related to a differential resonance of the two air bladder lobes which generally differ somewhat in size." This is a much greater variation than has hitherto been observed in any sounds of air bladder origin, even among variously sized individuals within the same species. For instance, principal frequencies exhibited by large and small specimens of the eel, thread herring, striped bass, gray squeteague, tautog, spadefish and New England toadfish usually vary by not more than 100 cycles (Fish, 1954). Therefore, the present authors consider that some other factor must have contributed to the reported 1,000 cycle difference in sea robin double sounds.

Although considerable underwater listening was carried on during December, 1956, and January, 1957, in areas where Bimini toadfish breeding had been observed in previous years and might again be expected, no sounds resembling the boat-whistle blast produced in Narragansett Bay by *O. tau* (Fish, 1954) during its early spawning season were recorded (Plate II, Fig. 7).

Tavolga (1958) recorded similar boat-whistle sounds on the Florida Gulf coast in late August, 1957, presumably produced by *O. beta,* a toadfish which breeds there during the winter months. Since no blasts of this type were detected during June, July and the first 20 days of August, he suggests that such soundmaking may precede the actual breeding period. Fish (1954) reported the *O. tau* boat-whistle sounds to be associated with pre-spawning activity of individuals, and to occur in the vicinity of the Rhode Island breeding grounds only during the

early part of the season; it was considered, therefore, as a possible mating call.

If the Bimini species is capable of such soundmaking, as seems probable, failure to record it could be due to scarcity of toadfish in those years or to the late start of field observations.

METHOD OF SOUND PRODUCTION

The sound-producing mechanism of the Bimini toadfish is provided by a large air bladder comprising approximately two-thirds of the visceral cavity; its mid-dorsal surface is rather loosely attached to the kidneys and margins are connected by peritoneum with the dorsal body wall. Anteriorly the air bladder is bilobed, with medial surfaces contacting each other in the mid-line. Each lateral wall is completely covered by a thick muscle mass with striated fibers running at right angles to its length; these intrinsic muscles meet but do not fuse posteriorly. Dorsal and ventral bladder surfaces are composed of tough fibrous tissue (Plate III, Fig. 8). Internally the two lobes unite to form a common chamber, walled posteriorly by a thin and somewhat vascular membrane. This transverse septum, which separates approximately one-third of the bladder into a posterior chamber, is perforated by a small central aperture (Plate III, Fig. 9). Except for greater prominance of red glands in the few specimens examined to date, the Bimini toadfish air bladder resembles that of *O. tau* both externally and internally.

Extensive experiment with *O. tau* has indicated (Fish, 1954) that sound is produced when, by contraction and expansion of the intrinsic muscle fibers, the taut membranous walls and gaseous contents of the air bladder are set in vibration. Probably sound waves are strengthened when the internal transverse septum is vibrated further by gas forced through its tiny aperture. Participation of pharyngeal teeth in ordinary sound production, although possible, has not been indicated in this species. Apparent similarity in sonic apparati leads to the conclusion that methods of sound production are identical in the two species of *Opsanus*.

CONCLUSIONS

Two general types of sound have been recognized for males of the Bimini toadfish; data are incomplete for female specimens. These sounds are sufficiently different from other *Opsanus* species to permit their use in making identifications, especially under field conditions where morphological comparisons are impossible. The chief distinction evident without physical analysis, is rapid repetition of many sound pulses into

a protracted burst, whereas *O. tau* and *O. beta* soundmaking features impulsive single or double pulses of sound.

On the basis of these records, it is suggested that the quality and pattern of underwater sounds may in some cases be included in taxonomic descriptions as a diagnostic specific character.

Determination of several characteristic patterns in the present *Opsanus* recordings have indicated that a single specimen may be capable of a variety of sounds, all produced by the large and heavily-muscled air bladder.

Experimental results indicate that biological underwater sound in this species is purposeful and occurs only in response to definite physical or physiological stimulation, as reported for many other fishes (Fish, 1954). The absence of the boat-whistle sounds associated with prespawning behavior of other *Opsanus* species may be due to a current scarcity of toadfish or to the late start of field observations.

BIBLIOGRAPHY

FISH, M. P.

1948. Sonic fishes of the Pacific. Pacif. Ocean. Biol. Project, Tech. Rep. 2: 1-144. (Woods Hole Ocean. Inst.).

1953. An outline of sounds produced by fishes in Atlantic coastal waters, sound measurements and ecological notes. Ocean. Biol. Project, Spec. Rep., 1: 1-21. (Narragansett Mar. Lab.).

1954. The character and significance of sound production among fishes of the western North Atlantic. Bull. Bingham Ocean. Coll., 14 (3): 1-109.

FISH, M. P., A. S. KELSEY, JR., & W. H. MOWBRAY

1952. Studies on the production of underwater sound by North Atlantic coastal fishes. J. Mar. Res., 11 (2): 180-193.

MOULTON, J. M.

1956. Influencing the calling of sea robins (*Prionotus* spp.) with sound. Biol. Bull. 3 (3): 393-398.

NAVAL ORDNANCE LABORATORY

1944. Investigations of biological underwater background noises in vicinity of Beaufort, N. C. (10B1). NOL Rep., 880: 1-22. (U. S. Navy Yard).

TAVOLGA, W. N.

1958. Underwater sounds produced by two species of toadfish, *Opsanus tau* and *Opsanus beta*. Bull, Mar. Sci. of the Gulf and Caribbean, 8 (3): 278-284.

TOWER, R. W.

   1908. The production of sound in the drum-
         fishes, the sea robin and the toadfish. Ann.
         N. Y. Acad. Sci., 18: (5) pt. II: 149-180.

WALTERS, V. & C. R. ROBINS

   MS. A new toadfish (Batrachoididae) regarded
       as a glacial relict in the West Indies.

PLATE I

FIG. 1. Single sound of specimen #3. Duration, 41
       milliseconds; 26 cycles present, damped
       in groups of 3; average repetition rate,
       634 cps.

FIG. 2. Double sound of specimen #3. Total dura-
       tion, 43 milliseconds. First pulse: 14 milli-
       seconds, 10 cycles present, average repeti-
       tion rate, 714 cps. Second pulse: 18 milli-
       seconds, 15 cycles present, average repeti-
       tion rate, 789 cps. Interval between pulses,
       11 milliseconds. Slightly more harmonics
       than in single sound of some specimen.

FIG. 3. Single sound of specimen #5. Duration,
       23 milliseconds; 5 cycles present; average
       repetition rate, 217 cps. Distorted wave
       form with at least 5 harmonics measur-
       able.

FIG. 4. Double sound A of specimen #5. Total
       duration, 58 milliseconds. First pulse: 23
       milliseconds, 5 cycles present, average
       repetition rate, 217 cps. Second pulse: 17

milliseconds, 4 cycles present, average
repetition rate, 235 cps. Interval between
pulses, 18 milliseconds.

PLATE II

FIG. 5. Double sound B of specimen #5. Total du-
       ration, 48 milliseconds. First pulse: 26
       milliseconds, 6 cycles present, average
       repetition rate, 231 cps. Second pulse: 13
       milliseconds, 3 cycles present, average
       repetition rate, 231 cps. Interval between
       pulses, 9 milliseconds. Similar in wave
       form and harmonic content to the single
       sound.

FIG. 6. Double sound C of specimen #5. Total
       duration, 57 milliseconds. First pulse: 7
       milliseconds, 2 cycles present, average
       repetition rate, 286 cycles. Second pulse:
       33 milliseconds, 8 cycles present, average
       repetition rate, 243 cps. Interval between
       pulses, 17 milliseconds.

FIG. 7. Typical intermittent blast of *O. tau* during
       its breeding season in Narragansett Bay.
       Individual contacts usually repeated at
       intervals of 30 seconds or more.

PLATE III

FIG. 8. Bimini toadfish with ventral body wall re-
       moved to show muscle-bordered air blad-
       der *in sitv.*

FIG. 9. Bimini toadfish after bisection of air blad-
       der to show internal transverse septum.